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3 Revolutions in Transportation

Following on from the focus of last month's topic on transportation and the 48th Annual A&WMA Critical Review by Dr. H. Christopher Frey, Drs. Dan Sperling and Austin Brown offer their perspective on the future of transportation, based on the book lead-authored by Dr. Sperling: *Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future* (Island Press, 2018).

We love cars. Or at least we love the freedom, flexibility, convenience, and comfort they offer. Cars provide great benefits, which is why they are popular. But they also impose huge costs on society in the forms of pollution, congestion, safety risks, and infrastructure construction and maintenance. Our transportation problems are exacerbated by the fact that the United States has fallen behind much of the rest of the world in providing affordable, fast, and reliable public transportation, resulting in more traffic congestion and disadvantaging those unable to buy and drive cars.

These downsides have long been acknowledged but not vigorously addressed because there were so few solutions. Now new services and technologies are at hand, with the potential to disrupt the status quo. The signs are all around us: Zipcar, Lyft, Uber, microtransit companies like Chariot and Via, dockless bikes and scooters, plug-in electric vehicles (EVs) from almost every major automaker,[1] hydrogen fuel-cell vehicles, and partially automated cars. Taken together, these innovations represent the "3 Revolutions" of electric, pooled, and automated vehicles.[2]

The 3 Revolutions can support a radically improved transportation system for all—if we play our cards right.[3] Electrification, pooling, and automation are progressing in distinct ways. But they are linked in that they offer profound opportunities for positive change, as well as a risk of unintended consequences.[4,5] Understanding how the 3 Revolutions are unfolding provides the insight needed to ensure that we realize the positive outcomes while avoiding undesired consequences.

Electrification

The modern advent of EVs followed decades of increasing research and development on batteries and power electronics.[6] A major EV milestone came in 2008 when Tesla launched its electric sports car, rocking the automotive world and proving that even high-end, high-performance vehicles could be electrified. Tesla followed up on this success in 2012, when it revealed its sleek and powerful Model S sedan. In 2010, Nissan introduced its Leaf, the first mass-market electric vehicle in almost 100 years. General Motors followed quickly with its plug-in hybrid Volt. Observing these impressive technological advances and seeking tools to address climate change, California rejuvenated its Zero Emissions Vehicle (ZEV) mandate in 2012, requiring automakers to ramp-up electric vehicle sales to roughly 15 percent market penetration by 2025. Nine other states embraced this same mandate, leading more and more Americans to switch to pure battery EVs, plug-in hybrid vehicles that combine batteries and combustion engines, and fuel cell EVs that run on hydrogen.

Electrification is also on the rise outside of the United States. Although global EV market penetration is still under 2 percent in 2018, it is much larger in some individual markets. Norway, for instance, saw market penetration of light-duty EVs approach 40 percent in 2017. EV sales in China soared to nearly a million in 2017,[7] double the previous year. Today, every major automaker in the world is investing massively in EVs. More than 40 different models are sold in the United States, and more are available elsewhere.

Experts expect a continued shift from conventional vehicles to EVs over the long term,[8,9] but the pace of change depends on technological development, sustained policy commitment, and shifts in consumer behavior. Recent progress in EVs has been driven, in part, by battery costs dropping faster than anticipated. Countries like Norway and China have positioned themselves as EV leaders by implementing massive subsidies and other aggressive policies. Outreach is also key.[10] In California, EVs captured 5 percent of the new car market in 2017, but given the incentives and other supports offered by the state, it was surprising that sales weren't higher. Increasing consumer education and buy-in will be necessary to achieve EV goals in California and elsewhere.

sharing a ride with other passengers, and accept a short detour to pick up and drop off those passengers. Pooling quickly gained steam. In 2016, only a year after the introduction of Lyft Line and UberPool, about half of users in San Francisco hailed a ride with their Pooled service (though many were not actually matched with other riders).[11]

The question now is how much further pooling can go. Shared rides has proved popular for those already using ridehailing apps, but single-passenger trips in privately owned vehicles still account for most of car-based travel. The small and dwindling[12] number of conventional carpoolers (i.e., people sharing rides outside of a designated service) in the United States, even given the inducement of carpool lanes in most major metropolitan areas, indicates that there are many obstacles that must still be identified and addressed for pooling to become widespread.

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Pooling

Pooling refers to encouraging vehicles to carry more than one passenger with an overarching goal of achieving more efficient use of vehicle capacity. Successful pooling reduces vehicle use while increasing mobility (passenger miles traveled). Pooling can also expand transportation options for lower-income, elderly, disabled, and other populations lacking the means or ability to drive their own private vehicles.

Smartphones have been the great enabler of shared mobility. Lyft and Uber were the first major companies to offer smartphone-enabled rides on demand. When these companies launched—Lyft in 2012, Uber in 2013—they were essentially glorified taxi services. They offered lower costs and greater convenience than regular taxis and were innovative in bringing the sharing and gig economies to ridehailing, but stuck to the conventional taxi model of passenger pick-ups and drop-offs. It didn't take long, though, before ridehailing expanded to pooling.

The introduction of Lyft Line in 2014 was game changing for pooling. Lyft Line enabled two or more strangers going in the same direction to easily share the trip. Uber quickly followed with its own version of ridesharing, UberPool. In both services, riders pay about two-thirds the normal price in exchange for

Pooling in new mobility services also depends on the companies ensuring the safety (both real and perceived) of users, who may be leery of the idea of sharing a ride with a stranger. The enormous benefits of pooling make it a prime candidate for public and private leadership, especially at the local level.

Automation

The third revolution, automation, is just beginning, at least when it comes to fully driverless cars (also known as autonomous vehicles, or AVs). Full automation is poised to be transformative and disruptive for many industries, including automakers, rental cars, infrastructure providers, and transit operators.

AVs once seemed like they belonged in some distant sci-fi future. First featured in the General Motors exhibit at the 1939 New York World's Fair and then demonstrated in the real world with General Motors and Honda cars in 1997, they are now nearing commercialization. In 2010, Google announced it had a car safely self-driving around the San Francisco Bay Area, with no special roadside infrastructure or city retrofitting.

Most new cars in Europe, the United States, Korea, and Japan are already partially automated. One common capability is adaptive cruise control, which allows the car to adjust its speed based on the speed of the car in front. Another is emergency braking, which allows the car to assume brake control when it detects an imminent crash. A third is lane-keeping and blind-spot assistance, meaning that the car alerts the driver when it is crossing a lane without a turn signal on or when another car is in the driver's blind spot. All of these features have been in commercially sold cars for several years.

Given how quickly partial automation has come to the mass market, it's easy to think that AVs are just around the corner. But in major transitions like this, success often requires more than technology. Several recent high-profile incidents have shaken the nascent public perception of highly-automated vehicles.[13] Getting AVs on the road requires new regulation around vehicle certification, licensing, and liability; corporate restructuring as businesses figure out how to adapt to an AV era; and public debates[14] over cybersecurity and ethical choices embedded in AV algorithms.

The Road Ahead

There is much uncertainty regarding how the 3 Revolutions will play out. Experts are confident that most cars will eventually become electrified and automated. With the right policies in place, pooling could become ubiquitous as well. Combining these three developments would make car-based travel far less expensive. Studies suggest that the cost of car-based travel could drop to as little as US$0.15 per passenger per mile from over US$0.50 today for a single-occupant gasoline car.[2,15] AVs also lower the time cost of car-based travel, since passengers can work, sleep, eat, converse, and so on while en route from point A to point B. This value of this time saving could be great, but it could also have adverse "rebound effects." If car-based travel becomes much cheaper and more pleasant, there is a risk of car usage skyrocketing—and with it, energy consumption and congestion—thereby offsetting many positive effects of the 3 Revolutions.

Expanding pooling is one solution to this potential problem, and one that will also help bring low-cost travel to disadvantaged populations. However, we have a ways to go before pooling accounts for more than a small fraction of total car trips. The dominant "shared vehicle" in 2017 was still Uber and Lyft cars carrying one passenger at a time. Discounted app-based pooling systems like Lyft Line and UberPool can flourish in cities, but don't work as well outside dense urban areas. The upshot is that the mere availability of pooling services doesn't guarantee their widespread use. Additional incentives may be necessary. Another important question is how to support AV integration into pooling. Google, Tesla, and Ford have all said they intend to put the first AVs into fleets for shared services, but legal and regulatory uncertainty about topics like liability and insurance may impede their ability to do so soon.

Resolving legal, regulatory, and policy uncertainty is also key to realizing safety benefits that automated vehicles can offer. Robot cars will—eventually, if not immediately—be far safer

than cars operated by humans. They won't drink and drive, get tired or distracted, and will have lightning reflexes. They can also learn from not just their own travel data, but from data collected by a growing, connected fleet of learning and sensing vehicles. Shifting to a driverless society could save as many as 30,000 lives per year in the United States and avoid millions of injuries. But if the transition from partially automated to fully driverless cars is delayed by safety regulators and governments (or anxious consumers), then we may not see changes in safety outcomes for many, many decades. Moreover, there is a risk that transportation-related deaths and injuries could increase if the transition is incomplete. As cars become equipped with more automated capabilities, human drivers pay less attention to what is happening on the road and so are unprepared to intervene in case of an emergency.

Public and private institutions must work together to successfully merge electrification, pooling, and automation. Perhaps the single most critical step is creating travel options that are safer, more convenient, more comfortable, and cheaper than driving a personal vehicle. When this happens, people will be motivated to give up their cars, setting us on a path to better, more sustainable transportation.

Simultaneously, governments must implement a policy framework that clearly addresses outstanding issues related to the 3 Revolutions, while remaining flexible enough to respond to new innovations. The framework should ensure prices of different transportation modes reflect impacts on societally relevant factors like congestion and pollution. For instance, governments could subsidize shared and electric travel, particularly at peak travel hours. The framework should also provide for greater investment in public transit or transit-like services that take cars off the road and expand equitable access to quality transportation. Other policies are needed to repurpose infrastructure that will become obsolete (e.g., gas stations unneeded by EVs or street signals unneeded by AVs) and develop new infrastructure that will become necessary (e.g., EV charging stations and sensors that can communicate wirelessly with computer-controlled cars), and to reform road and transit financing to reflect the needs of a new transportation era.

Transformation is coming to transportation. We must now decide how to respond. We can cross our fingers and hope that the future turns out well. Or we can apply our best thinking to make sure it does. By taking proactive steps now, we can harness vehicle electrification, pooling, and automation, to create better cities, a livable planet, and a future that serves us all. **em**

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